**Progress Report**
Office of International Health Programs (EH-63), Department of Energy

***Title of Project:*** **Dosimetric Support of the Ukrainian-American Eye-Cataract Study**

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***Period covered by this report:*** 1 October 1999 – 31 March 2000

## *I. Summary of Work*

During the preceding two-year period, the lists containing 33,505 names and addresses of the Chernobyl clean-up workers (liquidators) were assembled based on the principal criterion of availability of potentially good quality dosimetric data. These lists were forwarded to the epidemiological branch of the project, allowing thus to initiate and conduct ophthalmic examinations on regular basis. An abundant number of candidates (33,505 vs. 12,000 envisaged by the research protocol) allowed us to secure a significant reserve for possible natural reduction of the cohort size.

However, uncertainty of existing dose assessments which were incorporated into the study was not known beforehand. The criterion used for selection of candidates for follow-up – absence of intentionally falsified dose values – does not mean that all doses are of comparable and sufficiently high precision. In addition, no beta radiation doses to eye lens were available from the dosimetric monitoring files. Therefore, the tasks of the on-going work have two goals:

1. Retrospectively evaluate the uncertainties of the dose records, and
2. Develop an approach to assessment of doses to lens caused by beta radiation.

## *II. Milestones and Deliverables Accomplished during the Reporting Period*

During the current two year period several tasks and milestones were to be accomplished. The present report covers the first semester of the above mentioned biannual study and is structured according to the milestones of the implementation plan as envisaged by the biannual work proposal approved by the Office.

**Milestone 1.** ***Testing approaches and selection of the strategy to refine dosimetric data.***

The refinement of dosimetric data, retrospective evaluation of its uncertainty and other issues to be addressed in the planned work are quite new topics in the framework of UACOS. Therefore some time was needed for considering different approaches and the elaboration of the protocols for their implementation.

Upon considering various options and evaluating their general applicability and cost-effectiveness, the strategy for retrospective validation of official dose records was designed. Basically, the proposed strategy is as follows:

1. Inventory of all available individual dosimetry files and their linkage with the main Chernobyl database – the State Chernobyl Registry (SCR).
2. Statistical analyses of the dose record arrays in order to judge whether and to what extent they were falsified.
3. Reconstruction of dosimetric practices for each selected individual (liquidator).
4. Retrospective evaluation of the uncertainties associated with the dosimetric monitoring methods used at the time of clean-up.

Currently the status of the above tasks is as follows.

Task 1 is practically accomplished; all available electronic databases containing the results of dosimetric monitoring were acquired from both Ukrainian and Russian sources. This work yielded 168,394 unique dose records, mainly for the period 1986-1987. However, due to lack of confidence in identifiers (e.g. full names, dates of birth and passport numbers) only 1,901 cases could be successfully linked with the State Chernobyl Registry (SCR). In addition, 16,098 records were linked conditionally – the final judgement regarding the matching of data records may be achieved by personal contact with the liquidators and revealing the details of their clean-up activities. It is worth mentioning, that dosimetric monitoring databases are established on corporate basis, while SCR is missing data on the affiliations of the liquidators. In fact, the acquisition of the information regarding liquidator affiliations and their tasks in Chernobyl is covered by the Task 3 from the above list. Upon completion, this work would yield valuable information for reevaluation of the conditional linkages.

In the framework of Task 2, the methodology for evaluating the possible effects of administrative assignment of false doses was addressed by statistical analyses of dose records. We developed and tested the methodology on one of the groups of liquidators, namely – military reservists (also called in Chernobyl jargon "partisans"). This work will be continued on other groups of liquidators, once sufficient information is obtained from findings in Task 3.

The feasibility of Task 3 had been tested and now this information is being collected as the ophthalmic examinations proceed. Essentially, the mini-questionnaires of the type which was developed for the postal survey of liquidators are being filled out by liquidators during the course of their examination. An appropriate number of mini-questionnaire forms was provided to practitioners at each examination site. This work is very important. First, the questionnaire provides information about the affiliation of the liquidators. Thus we can categorize (stratify) the liquidator population and make some *a priori* judgement regarding dose management and dosimetric monitoring practices for given subjects. Second, as mentioned above, the mini-questionnaires provide a clue to the refinement of record linkage between dosimetric monitoring databases and personal files of the SCR. Finally, the survey of liquidators helps to determine the particular methods of dosimetry which were used to create dose records. This is especially important, because it helps to assign certain dosimetric methods (and, respectively, typical uncertainties) to given persons. Moreover, this information is very important for implementing Task 4 (retrospective evaluation of uncertainties) because it helps to establish uniform groups to validate existing dose records vs. independent reference dose estimates. This will allow us to

identify random error term and systematic bias attributed to given methods of dosimetry at time of clean-up.

Task 4 is a retrospective evaluation of the uncertainties associated with the dosimetric monitoring methods used at the time of clean-up. At the time of the initiation of this work it was really open-ended in the study design so various approaches have been considered during the reporting period.

In general, retrospective validation of historical dose records and the assessment of the uncertainties are not new problems. Many sets of individual dosimetric monitoring data obtained in previous decades required dosimeter-type testing and the assessment of the uncertainties associated with the particular systems used for personal dosimetry. In our case, such an approach may be applied only to part of the data, namely, to the results of instrumental measurements (TLD, alumophosphate glass or ionization-chamber dosimeters). The remainder of the dose records was obtained by "group-monitoring" or "group-assessment"* methods. These of course are associated with higher and uncontrolled uncertainties. In these methods, instrumental error is a minor contributor to the overall uncertainty, which is primarily due to variations in behavior and to uncertainties in the contamination of workplaces. Obviously, the unique working conditions of the Chernobyl clean-up cannot be repeated for "type testing" of these methods. In addition, and computer simulation is also facing serious problems, mainly due to the lack of data on the distribution of the radiation fields (and on their kinetics) as well as on behavioral patterns.

Therefore, the retrospective evaluation of the uncertainties related to "group" methods requires relative calibration requiring the comparison of ODR with more precise estimates.

Upon rigorous analyses and consideration it was concluded that EPR dosimetry utilizing teeth may serve as a reference for such calibration (this instrumental technique has an error of about 30% at doses above 100 mGy). The Figure 1depicts the relationship between ODR and EPR dose estimates for 14 subjects. Although qualitatively an agreement is observed, the sample size is insufficient to make any quantitative judgement regarding the accuracy of ODR. However, in practical terms, EPR dosimetry should be applied to representative samples of liquidators, for which doses were obtained using different methods of dosimetry monitoring. If a selected sample is indeed representative and numerous enough to have sufficient statistical power, the result of such calibration will be expressed in terms of offset and random errors associated with the considered method of dosimetric monitoring. If little or no correlation with the reference method (EPR) is found, dose records obtained with the failing method will be rejected from the epidemiological consideration. These tests should be applied to distinct groups of liquidators separately, thus increasing the total number of test subjects. One may expect that from several hundred to some thousands of subjects would be involved in the described cross-calibration. The strength and weakness of tooth EPR dosimetry and, in particular, scientifically justified limitations of its application are described in the respective section of the present report (*III. Other relevant information*).

Another approach to refine the dosimetric data by applying a universal method (e.g. Soft Expert Assessment Dosimetry - SEAD) was tested during the reporting period as well. Totally 145 subjects were interviewed and analyzed by SEAD. Unfortunately, quite poor correlation with

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* According to the "group-monitoring" method, an individual dosimeter was provided to only one member of a group of liquidators assigned to perform a particular task, and all members of the group were assumed to receive the same dose.
According to the "group-assessment" approach, doses were evaluated by a dosimetrist on the basis of the dose rate at the working place and of the duration of work; such single dose assessment was assigned to the whole group of liquidators performing a similar task.

independent (reference) dose estimates was observed. Although closer consideration of each of the cases allowed isolation of the likely sources of uncertainties, one cannot expect complete success in routine application of the method like SEAD for bulky dosimetric screening of study subjects. Now the research is being concentrated on both the development of an expert judgement approach (this envisages possibility to assess the trustworthiness of official dose records from consideration of actual tasks, locations and periods of work). In addition we are considering a development of a computer aided version of time-and-motion (so-called analytical) dose reconstruction. Anyhow, it does not seem realistic to perform dosimetric screening of all 12,000 members of study cohort – interview the subjects with quite elaborate questionnaire, analyze responses to the questionnaire, make expert consideration on individual basis. Therefore, the method of choice would be the above outlined four step procedure, which, in particular, incorporates assignment of group-specific error estimates based on retrospective assessment of uncertainties for isolated groups of liquidators.

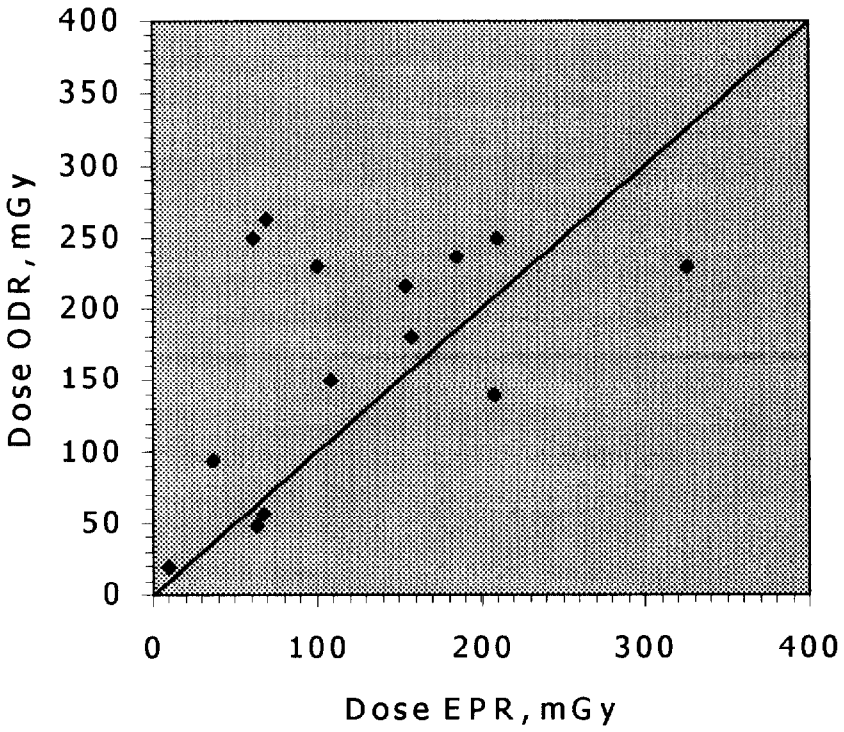


Figure 1. Comparison of ODR doses (official dose records) and EPR doses (results of EPR dosimetry). 14 subjects, mainly "partisans".

**Milestone 2.** ***Verification of previously acquired dose records.***

Once the strategy of dose refinement and validation had been chosen, the work on assembling the groups for close dosimetric consideration began. So far, the following groups (categories) of liquidators have been selected: military reservists ("partisans"), professional atomic workers and individuals sent on mission (SOM). The latter category involved a large population and includes a wide variety of liquidators who had visited Chernobyl performing rather limited and, as a rule, short term missions. It is planned to consider 100-150 individuals in each group providing thus sufficient statistical power to the results of such a test. So far, mainly partisans have been enlisted

into the described study, however work on assembling sufficient sample for both professionals and SOM is now in progress.

**Milestone 3.** ***Retrospective evaluation of uncertainties associated with dose records.***

The work on this milestone is currently in progress. The typical methods of dosimetry are being identified from the results of a mini-questionnaire survey of the Liquidators. The breakdown of different groups of liquidators by their methods of dosimetry is presented at Fig.2.

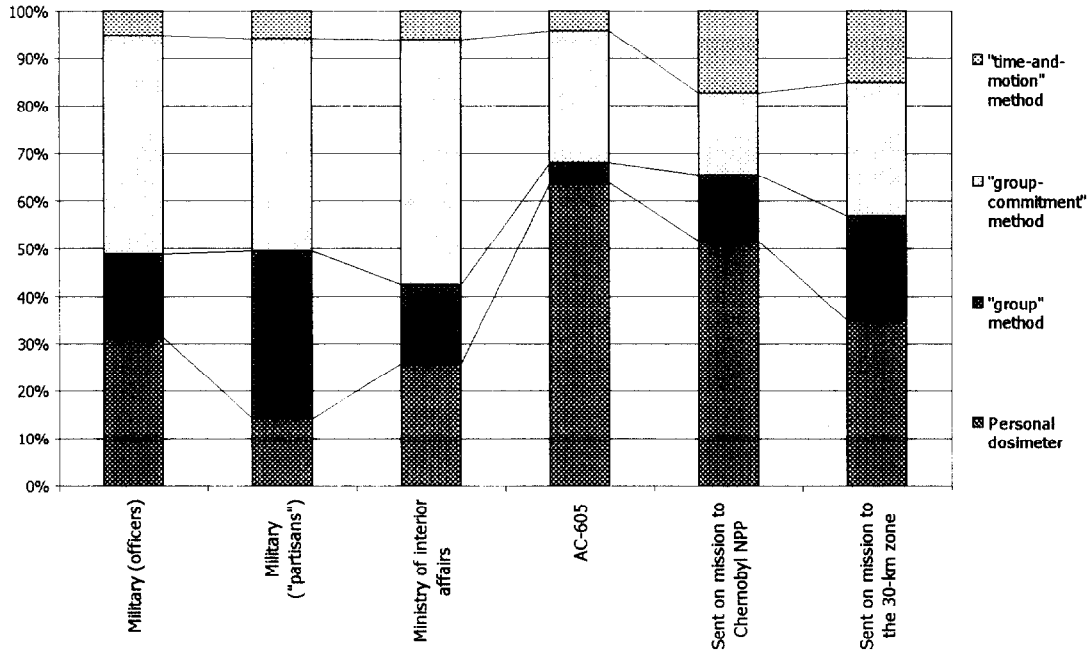


Figure 2. Dosimetric methods used for monitoring of different groups of liquidators – results of postal survey.

The results of the study of monitoring methods are quite informative. The highest coverage by instrumental monitoring was found for the staff of AC-605 (i.e. professional atomic workers). It was determined that for military ("partisans") in many cases (>80%) dose records were assigned by group-monitoring (one dosimeter for a group of liquidators) and group-assessment (calculation in advance) methods. Personal dosimetry was applied only in less than 15% cases. The information acquired in the course of this survey give a clue to stratification of the liquidator population according to the dosimetric monitoring practice, tasks and places of work at time of clean-up. This data will be used for retrospective evaluation of uncertainties associated with individual dose records.

However, for the time being, some *a priori* assessments of uncertainties as associated with given dosimetric methods are as following:

- Individual instrumental monitoring (error 30-40%)
- "Group-monitoring" method (uncertainty 70-100%)
- "Group-assessment" method (uncertainty >300 %)

However, these estimates based, to large extent, on expert judgement, need to be confirmed and/or updated in course of the exercise described above.

**Milestone 4.** ***Evaluation of beta doses.***

During the reporting period, work on assessing beta dose was focused on establishing the capability to evaluate beta/gamma ratios for given periods of time and conditions of exposure. Briefly, the methods for independent evaluation of beta doses by point source analytical expression (derivative of the Loevinger function) as well as implementing the more precise, yet more labor and time intensive Monte Carlo procedure were deployed for assessing the same dosimetric value. The need for such cross-calibration was determined by the fact that point source functions have problems when composite media (like soil-air-tissue) are involved. Therefore, prior to making wide use of more easily applicable point source calculations, we should first perform benchmark calculations using the results of Monte Carlo analysis as a reference. During the reporting period, both Monte Carlo (code MCNP-4B) and point source (home made program) were installed and some test calculations were made. In the coming semester all necessary calculations will be completed providing thus values and possible ranges of beta-to-gamma ratios. Depending on the results of these calculations (estimated ranges of the above mentioned ratio) the decision will be made on significance of the parameters (conditions) of exposure and their effect on the beta/gamma ratio. The most significant parameters will be incorporated into the beta assessment model, while less important ones will be left out of consideration.

**Milestone 5.** ***Integration of individual dose estimates.***

The work on this milestone was scheduled for the later period, when best of our knowledge dose estimates along with their uncertainties will become available.

***III. Other relevant information***

Among the existing methods of retrospective dosimetry, tooth enamel EPR occupies a rather unique place. First of all, EPR dosimetry is the only instrumental method with strictly quantifiable accuracy. Second, the errors associated with this technique (about 30% at doses higher than 100 mGy) are comparable to uncertainties typical of many conventional methods of dosimetric monitoring.

At the same time, EPR dosimetry has drawbacks that limit its application:

1. A sensitivity threshold below which doses cannot be determined; presently this threshold is about 50-100 mGy.
2. A relatively high labor intensive analysis and a need for sophisticated hardware.
3. Confounding factors (e.g., lifetime medical x-ray exposure and UV exposure) which may alter (overestimate) dose values. In order to prevent severe mistakes in dose reconstruction, the teeth which are known to have dental x-ray exposure and front teeth, which have enhanced solar UV exposure, are excluded from consideration, thus reducing the number of appropriate samples.

4. Difficulties of obtaining samples for analysis. Since teeth are extracted for medical reasons only, EPR dosimetry is being performed on these randomly collected specimens.

However, regarding the problem of liquidators dosimetry, the overall balance is positive. Doses of the majority of liquidators are higher than 50 mGy, deficiencies associated with the availability of samples are being addressed by a systematic nationwide acquisition of teeth from liquidators, the labor intensive nature of dose reconstruction has been significantly reduced by optimizing sample preparation and measurement protocols. Moreover, there are possibilities for transforming the EPR dosimetry from a "state-of-the-art" technique to a routine high performance tool with overall throughput of several thousands analyses per annum.

Therefore, EPR dosimetry is considered as a source of reference dose for the purpose of calibration of other methods as well as a method for high precision dose reconstruction in some particular cases.

## *IV. Publications*

1. Chumak V.V., Sholom S.V., Pasalskaya L.F. Application of high precision EPR dosimetry with teeth for reconstruction of doses to Chernobyl populations. *Radiat.Prot.Dosim.* Vol. 84, Nos. 1-4, pp. 515-520.
2. Chumak, V.; Krjuchkov, V.; Bakhanova, E. and Musijachenko, N. Dosimetric Monitoring at Time of Chernobyl Clean-up: A Retrospective View. Proceedings of The 10$^{th}$ International Congress of The International Radiation Protection Association, May 14-19, 2000, Hiroshima, Japan (in press).
3. Chumak, V.; Bouville, A.; Bakhanova, E.; Krjuchkov, V.; Sholom, S. and Pasalskaya, L. Retrospective dosimetry of Chernobyl liquidators. Proceedings of The 10$^{th}$ International Congress of The International Radiation Protection Association, May 14-19, 2000, Hiroshima, Japan (in press).